BIOECONOMY IN THE AMAZON

BIOECONOMIA NA AMAZÔNIA

BIOECONOMÍA EM LA AMAZONÍA

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ABSTRACT

Bioeconomy in the Amazon emerges as an alternative for sustainable development, combining biodiversity preservation with the generation of economic value from natural resources in a responsible way. The Amazon region, rich in biological and cultural diversity, holds significant potential for creating production models based on sustainable practices, promoting social inclusion, and strengthening local communities. This article explores the main aspects of bioeconomy in the Amazon, including the productive chains of sociobiodiversity, social technologies and innovations, the challenges faced, and future prospects. Moreover, it discusses the importance of biofuel production as part of this transition towards a greener and more inclusive economy.

Keywords: Bioeconomy. Amazon. Sociobiodiversity. Innovation. Sustainability.

RESUMO

A bioeconomia na Amazônia surge como uma alternativa para o desenvolvimento sustentável, combinando a preservação da biodiversidade com a geração de valor econômico a partir dos recursos naturais de forma responsável. A região amazônica, rica em diversidade biológica e cultural, possui um grande potencial para a criação de modelos de produção baseados em práticas sustentáveis, promovendo a inclusão social e o fortalecimento das comunidades locais. Este artigo explora os principais aspectos da bioeconomia na Amazônia, incluindo as cadeias produtivas da sociobiodiversidade, as tecnologias sociais e inovações, os desafios enfrentados e as perspectivas para o futuro. Além disso, discute a importância da produção de biocombustíveis como parte dessa transição para uma economia mais verde e inclusiva.

Palavras-chave: Bioeconomia. Amazônia. Sociobiodiversidade. Inovação. Sustentabilidade.

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RESUMEN
La bioeconomía em la Amazonía surge como uma alternativa par el desarrollo sostenible, combinando la preservación de la biodiversidade com la gerneración de valor económico a partir de los recursos naturales de manera responsable. La región amazónica, rica em diversidade biológica y cultural, tiene un gran potencial para la creación de modelos de producción basados em prácticas sostenibles, prooviendo la inclusión social y el fortalecimento de las comunidades locales. Este artículo explora los principales aspectos de la bioeconomía em la Amazonía, incluyendo las cadenas productivas de sociobiodiversidad, las tecnologias e innovaciones sociales, los desfíos enfrenados y las perspectivas de futuro. Además, analisa la importância de la producción de biocombustibles como parte de esta transición hacia uma econmía más verde e inclusiva.

Palabras clave: Bioeconomía. Amazonía. Sociobiodiversidad. Innovación. Sostenibilidad.

1 INTRODUCTION

The bioeconomy emerges as a paradigm that redirects the global production model by using renewable bio-based resources to generate food, fibers, biofuels, pharmaceuticals, and ecosystem services with less environmental impact (Molesti, 2010). Supported by circular economy principles, it seeks to close cycles of matter and energy, reduce waste and value by-products. In the Amazonian context, where 20% of the planet's surface fresh water and about 10% of global biodiversity are concentrated, the bioeconomy offers unique opportunities for innovation and regional development (Virgínio and Barbosa, 2022).

The Brazilian Legal Amazon, with its 5,090,000 km², is home to indigenous, riverside and quilombola populations, holders of millennial knowledge for the sustainable management of natural resources. The açaí production chain, for example, involves more than 200,000 extractive families, generating about R$ 2 billion annually (IBGE, 2022). However, limitations such as the precariousness of roads, electricity and ports, as well as land conflicts, reduce competitiveness and insertion in high value-added markets (Corrêa and Ramos, 2010).

Given this scenario, this review is justified by consolidating scientific evidence and empirical data that support innovative policies and practices for the bioeconomy in the Amazon. The objectives are: (i) to map the main concepts and theoretical frameworks; (ii) assess the state of the socio-biodiversity chains; (iii) analyze benefit-sharing mechanisms; (iv) identify technological advances; and (v) discuss the framework of public policies and governance.

2 MATERIALS AND METHODS

The review was carried out between March and April 2025. The Scopus, Web of Science, SciELO and Google Scholar databases were consulted, in addition to reports from EMBRAPA, INPA and BNDES. The following descriptors were used: "bioeconomy", "Amazon", "circular economy", "sociobiodiversity" and "technological innovation". Empirical articles, systematic reviews, and case studies published between 2010 and 2024, in Portuguese, English, and Spanish, that directly addressed the Legal Amazon, were included. Opinions, editorials, explicitly outside the regional scope or without quantitative data were excluded.

2.1 CONCEPTUAL FOUNDATIONS OF THE BIOECONOMY AND CIRCULAR ECONOMY

The **bioeconomy** is an interdisciplinary concept that has gained prominence in debates on sustainable development and ecological transition (Gama and Brasileiro, 2024). According to these authors, it is based on the use of renewable biological resources such as

plants, microorganisms, organic residues and forest or agricultural biomass, to produce goods and services in a sustainable way. This approach proposes to gradually replace fossil resources with renewable resources, promoting the decarbonization of the economy, technological innovation, and the valorization of biodiversity (Caminha, 2022).

From the point of view of the Organization for Economic Cooperation and Development (OECD), the bioeconomy is defined as the economy that encompasses "all economic activities associated with the invention, development, production, and use of biological products and processes (Costa *et al*., 2022). In the Brazilian context, the Ministry of Science, Technology, and Innovation (MCTI) includes sectors such as agriculture, forestry, fisheries, industrial biotechnology, health, and bio-based products in the bioeconomy, emphasizing the integration of scientific knowledge, innovation, and environmental sustainability (Lago, 2024).

The **circular economy**, in turn, is an economic model that proposes the reconfiguration of production chains so that they operate in closed cycles, in which waste is minimized, materials are continuously reused, and natural resources are preserved (Oliveira, Silva, and Moreira, 2019). According to these authors, this model is opposed to the traditional linear logic of "extract, produce, discard", proposing the principles of the 3Rs — reduce, reuse and recycle — in addition to the regeneration of ecosystems. The circular economy is intrinsically linked to the bioeconomy, as both promote efficiency in the use of resources, but while the bioeconomy focuses on replacing fossil raw materials with renewable ones, the circular economy emphasizes **maintaining the value of resources over time (Grandisole, 2024).**

The synergy between bioeconomy and circular economy is essential to address global challenges related to climate change, biodiversity loss, and natural resource scarcity (Àzara *et al*., 2025). The integration of these approaches allows, for example, agro-industrial waste to be transformed into bioenergy, bioplastics, or organic fertilizers, adding economic value and avoiding environmental impacts (Oliveira *et al*., 2025). Data from the Ellen MacArthur Foundation (2019) indicate that the adoption of circular strategies can reduce global greenhouse gas emissions associated with production systems by up to 45%, which is particularly relevant in regions such as the Amazon, where biological potential is abundant, but environmental pressure is also intense.

In the Amazon scenario, strengthening the bioeconomy requires that these two approaches, bioeconomy and circular, be applied in an integrated manner (Caldas *et al*., 2023). Products such as copaiba oil, latex, and Amazonian fruits can be extracted and processed in a way that generates circular, low-impact, high-value-added chains, as long as

they respect ecological limits and ensure fair sharing of benefits. Thus, the development of a circular bioeconomy in the Amazon constitutes a promising strategy for sustainable socioeconomic growth, combining science, innovation, valuing biodiversity, and the role of local communities.

2.2 SOCIO-BIODIVERSITY PRODUCTION CHAINS

Sociobiodiversity **production chains** represent one of the pillars of the Amazonian bioeconomy, as they articulate traditional knowledge, biological diversity and income generation for local communities (Abrantes, 2003). According to the Ministry of the Environment, socio-biodiversity products are those that come from sustainable extractivism and family farming, whose origin is associated with native species and traditional use by indigenous peoples, quilombolas and riverside dwellers, and the valorization of these chains makes it possible to conserve forest ecosystems while promoting socioeconomic inclusion (Brasil, 2009).

According to Euler, Albertin, and Cialdella (2023), in the Amazon, chains such as **açaí (*Euterpe oleracea*), Brazil nut (*Bertholletia excelsa*)**, **andiroba oil (*Carapa guianensis*)**, **cupuaçu (*Theobroma grandiflorum*),** and **murumuru (*Astrocaryum murumuru*)** stand out. In 2022, non-timber plant extractivism moved around R$ 1.8 billion in the Amazon region, with Pará and Amazonas leading the production (IBGE, 2022). Açaí, in particular, is one of the most exported products, with expanding markets in Europe, the United States, and Japan, due to its high concentration of antioxidants and potential as a functional food (Brasil, 2024).

However, these chains still face structural challenges. The lack of adequate infrastructure such as roads, electricity and processing facilities limits the added value of products (Torres, Lima Filho and Belarmino, 2013). In addition, according to these authors, many producers operate informally, which hinders access to credit, technical assistance and certifications, thus making traceability and sanitary regularization other recurrent obstacles, especially for insertion in international markets.

Initiatives such as the **"Bioeconomy of the Amazon" project**, funded by FINEP and coordinated by institutions such as EMBRAPA and IDESAM, have sought to reverse this scenario through the use of tracking technologies such as blockchain, agroforestry systems, and technical training (Silva and Girard, 2025). The adoption of certifications such as the Origens Brasil Seal, the FSC, and the organic has allowed extractive communities to increase the sale value of their products by up to 25%, as pointed out by reports by FAS (Fundação Amazonas Sustentável, 2022). Such advances demonstrate the potential of socio-biodiverse chains as foundations of an inclusive and regenerative bioeconomy.

2.3 TRADITIONAL KNOWLEDGE AND BENEFIT-SHARING

Traditional **knowledge associated with biodiversity** is an essential component of the bioeconomy in the Amazon, as it reflects knowledge accumulated over generations by indigenous peoples, quilombola, riverine and extractive communities on the sustainable use of plant, animal and microorganism species (Freire, 2022). This knowledge guides practices of management, curing, feeding, cultivation, extraction and environmental preservation that are fundamental for the rational use of natural resources and for the development of innovative bioeconomic products.

The importance of traditional knowledge is recognized both nationally and internationally. The **Convention on Biological Diversity (CBD),** ratified by Brazil in 1994, establishes that States must respect, preserve and maintain traditional knowledge relevant to the conservation of biodiversity, in addition to promoting the fair and equitable sharing of the benefits derived from its use (Brasil, 1992). This premise was incorporated into **Law No. 13,123/2015**, known as the Biodiversity Law, which regulates access to genetic heritage and associated traditional knowledge in Brazil, creating rules for the **sharing of benefits** with the communities that hold this knowledge.

According to Brasil (1992), in practice, this sharing can occur through **monetary benefits** such as a percentage of profits, royalties or direct financial transfers, as well as through non-monetary **benefits** such as technology transfer, training, institutional support or improvements in community infrastructure. An emblematic case was the benefit-sharing agreement signed between the company Natura and communities on the Iratapuru River, in Amapá, involving the traditional use **of Brazil nut oil** in cosmetics (Souza, Vieira and Cañete, 2018). According to these authors, the agreement guaranteed annual financial transfers and social investments, in addition to strengthening community governance and the economic autonomy of the local population.

Despite the legal advances, the effectiveness of benefit sharing still faces challenges. Many communities do not have formal documentation of their knowledge, which makes it difficult to legally recognize and protect against biopiracy (Dias, 2025). According to this author, in addition, bureaucracy and the lack of technical assistance compromise the registration of communities in the **National System for the Management of Genetic Heritage and Associated Traditional Knowledge (SisGen),** which is the official tool for regulating access and benefit sharing in Brazil.

Valuing traditional knowledge in the Amazonian bioeconomy also requires the strengthening of **citizen science**, **participatory ethnobotany,** and **intercultural dialogue** between researchers, companies, and local communities (Costa *et al*., 2022). These authors

illustrate experiences such as the **Socio-Environmental Institute (ISA),** the **Bionorte Network** and the **Ethnodevelopment** programs promote this articulation by recognizing traditional populations as co-authors of bioeconomic innovations, and not only as suppliers of raw materials.

In this context, traditional knowledge is not only a source of information on the uses of biodiversity, but also expresses **its own worldviews** on ways of life and relationships with nature. Incorporating this knowledge into bioeconomy projects strengthens socio-environmental justice and avoids the decontextualized commodification of Amazonian biodiversity, contributing to more ethical, inclusive, and sustainable economic models (Rocha, Boscolo, and Fernandes, 2015).

2.4. SOCIAL TECHNOLOGIES AND INNOVATION IN THE AMAZON BIOECONOMY

The bioeconomy in the Amazon demands technological solutions adapted to the sociocultural, economic, and environmental realities of the region (Diniz and Reynol, 2023). According to these authors, in this sense, **social technologies, which are** understood as products, techniques and methodologies developed in interaction with communities and aimed at solving local problems, become fundamental tools to promote productive inclusion, autonomy and sustainability in socio-biodiversity chains.

Unlike conventional technologies, social technologies are created and applied based on the **empirical knowledge of communities**, seeking to respect traditional knowledge, value local protagonism, and promote the rational use of natural resources (Souza and Pozzebon, 2020). As these authors cite, relevant examples include rainwater harvesting and treatment systems, community vegetable oil processing units, solar dryers for seeds and fruits, manual açaí pulpers, ecological ovens and mobile biofactories.

In the Amazonian context, initiatives such as the **"Amazon 4.0"** project, led by physicist Carlos Nobre, have contributed to the development of **itinerant technological innovation laboratories**, equipped with 3D printers, quality analysis modules, and tools for the local processing of forest products (Nobre and Nobre, 2019). These mobile units allow communities to add value to biodiversity in their own territory, avoiding predatory extraction and dependence on intermediaries.

Another important example is the work of **EMBRAPA Western Amazon**, which has developed technologies for the processing of cupuaçu and fine cocoa in partnership with agroextractivist cooperatives, promoting certified products with gourmet quality. These actions enable the insertion of small producers in high value-added market niches, such as the *bean-to-bar* chocolate market and natural cosmetics (Lima and Cabral, 2022).

In addition, innovation in the Amazon bioeconomy also occurs through digital platforms and traceability solutions, such as the use of ***blockchain*** to ensure the sustainable origin of forest products (Caminha, 2022). The **Origens Brasil platform**, for example, connects traditional communities to conscious buyers, promoting ethical and transparent business relationships and this initiative has already benefited more than 35 thousand people in protected areas of the Amazon, promoting fair trade and valuing the way of life of local populations (Lago, 2024).

Social **innovation incubators and networks**, such as **INPA Social**, the **Mamirauá Institute**, and the **Amazon Entrepreneurship Center**, also play a central role in training young leaders, strengthening cooperatives, and developing startups focused on sustainable solutions (Jordano, 2014). These networks connect science, technology, innovation, and local knowledge, contributing to the emergence of sustainable and community-based productive arrangements.

Thus, the advancement of the Amazonian bioeconomy requires investments in participatory research, policies to encourage inclusive innovation, and the expansion of partnerships between universities, research centers, the private sector, and traditional communities. Social technologies are strategic instruments to address inequality, promote the sustainable use of biodiversity, and build resilient economic alternatives in the face of the climate crisis and pressures on the forest (Ventura, Garcia, and Andrade, 2012).

2.5 CHALLENGES AND PERSPECTIVES FOR AN INCLUSIVE BIOECONOMY IN THE AMAZON

The construction of an inclusive bioeconomy in the Amazon faces multiple **structural, institutional, and cultural challenges**, which require integrated responses from the State, science, the private sector, and local communities. Despite the enormous potential of the region, which is home to about 20% of the world's biodiversity and more than 30 million inhabitants, the bioeconomy has not yet consolidated itself as a hegemonic vector of development, often being replaced by predatory activities, such as deforestation for extensive cattle ranching, land grabbing, and illegal mining (Fernandes et al, 2022).

One of the main obstacles is the **lack of basic infrastructure and logistics**, which compromises the flow of production, the proper storage of socio-biodiversity products, and access to consumer markets (Ewert and Tararan, 2024). Many riverside and indigenous communities remain geographically isolated, facing difficulties in transportation, access to electricity, the internet and drinking water, which are essential elements for the operation of processing units and for local technological development.

Another critical challenge is the **fragmentation of public policies** aimed at the bioeconomy. Important initiatives such as the **National Bioeconomy Plan**, state programs such as the Amazonas State Bioeconomy Policy, and international funds such as the Amazon Fund and the GCF still lack effective articulation, administrative continuity, and alignment with local realities (Furtado, 2024). Bureaucracy, political instability, and the absence of efficient governance mechanisms make it difficult to apply resources and implement long-term sustainable projects.

From a social point of view, the **need to guarantee protagonism and autonomy to traditional populations is** highlighted, avoiding their subordination to extractive exploitation models controlled by large companies or external actors (Eidt and Udry, 2019). An inclusive bioeconomy must prioritize cultural appreciation, territorial security, fair sharing of benefits, technical and scientific training of local youth, and the strengthening of community organizations. According to Eidt and Udry (2019), the **legal recognition of territories** as indigenous lands, extractive reserves, and sustainable settlements is an essential condition for the protection of the forest and the implementation of economic models based on conservation and innovation.

In addition, there is a **mismatch between scientific production and the practical application of knowledge** in Amazonian communities. Many studies and technologies developed in urban centers in the Southeast and South of Brazil do not dialogue with local needs and specificities. To overcome this barrier, it is essential to foster regional science and technology networks, such as the **BIONORTE Network**, and to strengthen Amazonian institutions such as **INPA, IDAM, UFAM**, **IFAM,** UEA and research centers in the Amazonian states.

In terms of **perspectives**, the bioeconomy has the potential to consolidate itself as an economic strategy that aligns biodiversity conservation with income generation and reduction of inequalities (Furtado, 2024). The advancement of sustainable production chains, such as native cocoa, Brazil nuts and Amazonian herbal medicines, opens opportunities in international markets focused on ethical, organic and traceable products. Sectors such as **natural cosmetics**, **phytotherapy**, **nutraceuticals**, and **biocompatible materials** show strong growth and can incorporate Amazonian inputs in a fair and innovative way.

Another promising horizon is in **technical and technological education** aimed at Amazonian youth (Crux, 2022). According to this author, the creation of **bioeconomy schools**, technical courses and scientific extension programs can stimulate a new generation of entrepreneurs and researchers committed to the sustainable use of the forest. Fostering

green startups, community biofactories, forest-based agro-industrial hubs, and cooperative networks is vital for building an innovation ecosystem rooted in the regional reality.

Therefore, although the challenges are significant, the bioeconomy in the Amazon represents a concrete alternative to the current predatory model, offering paths for development based on standing forest, traditional knowledge, and inclusive innovation. For this transition to occur in a fair and effective way, multisectoral engagement and respect for the sociocultural diversity of the region are essential.

3 CONCLUSION

The bioeconomy in the Amazon is configured as a development model that combines environmental conservation, valorization of traditional knowledge and technological innovation, being able to respond to multiple challenges faced by the region. From the understanding of the conceptual foundations of the bioeconomy and the circular economy, the importance of redesigning Amazonian production systems with a focus on the regeneration of ecosystems, the reuse of waste and the efficient use of natural resources is evident. This approach, in addition to reducing environmental impacts, promotes the socioeconomic insertion of local populations in sustainable production chains. The socio-biodiversity production chains demonstrate, in turn, that there is great potential for generating value and income with non-timber forest products, as long as sustainable practices are adopted, associated with traceability and social inclusion. Social technologies and innovations adapted to the Amazonian context reinforce this path, by promoting autonomy, adding value in the territory, and articulating science and traditional knowledge.

Even so, several obstacles persist, such as the deficiency in infrastructure, the fragmentation of public policies and the historical exclusion of traditional peoples from economic decisions. In this scenario, the production of biofuels emerges as a strategic opportunity both to diversify the regional energy matrix and to strengthen community-based productive arrangements. Native oilseeds, agro-industrial residues and clean technologies can compose sustainable energy systems, with a positive impact on the local economy and the environment. To consolidate a bioeconomy in the Amazon, a political and social pact is needed that involves the State, local communities, research centers, civil society, and the productive sector. It is essential to guarantee access to land, education, technology and the market, in addition to recognizing the strategic role of the standing forest and traditional knowledge in building a sustainable future. When guided by principles of socio-environmental justice and territorial governance, the bioeconomy can transform the Amazon into a global example of development based on diversity, innovation, and life.

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